OBSERVATIONS ON PLANORBIS.

BY ROBERT E. C. STEARNS.

I. *Are the Shells of Planorbis Dextral or Sinistral?*

Incidental to an investigation into the relations of certain fresh-water snails, upon looking through the books, I find that authorities differ on the point, whether the shells of *Planorbis* are dextral or sinistral.

While Say,[1] Swainson,[2] G. B. Sowerby, Jr.[3] and Reeve[4] regard them as sinistral, or reversed, and properly figure the shells, in their works, in a sinistral position, and not "upside down," as in many of the books, Macgillivray[5] says "the shell is dextral, as several observers have proved; not sinistral, as many have alleged;" and Woodward,[6] H. and A. Adams,[7] W. G. Binney[8] and others also describe it or refer to it as being dextral.

Dall remarks in a foot-note to his paper "On the Genus Pompholyx and its Allies,"[9] "if we consider the shells of this group as dextral, they offer the peculiarity of having the genitalia as in most sinistral shells; *Pompholyx* presents the same conditions and is certainly dextral." Dr. Philip P. Carpenter, referring to *Planorbis*, says, "it lives in a reversed position."[10]

It will be observed from the above that eminent writers are divided, and that we have substantial authority on both sides of the question.

My own observations thus far prove the shells to be generally *sinistral*,[11] but as I have examined but comparatively few of the whole number of species, it may be that the shells in some species are dextral, and in other species sinistral.

[1] Say ex Binney, L. and F. W. Shells of N. A., Part II, p. 103.
[2] Treatise on Malacology, p. 337.
[3] Conchological Manual, p. 245.
[4] Conchologia Systematica, Pl. CXC.
[5] Molluscous Animals of Scotland, p. 114.
[6] Manual of Mollusca, second ed., p. 302.
[7] Genera of Recent Mollusca, Vol. II, p. 260.
[8] Smithsonian Miss. Pub. No. 143, p. 103.
[9] Annals of Lyceum of Nat. History of N. Y., Vol. IX, March, 1870.
[10] Lectures on Mollusca, S. I. Report, 1860.
[11] The figures of Say's larger species in Gould's Invertebrata of Mass., first ed., are most excellent.

G. B. Sowerby, Jr., in comparing *Planorbis* with certain Ampullariæ (*Marisa*), says: "It is further to be remarked that the discoidal Ampullariæ are dextral shells, and the Planorbes are sinistral or reversed; and although the latter are sometimes so flat and orbicular that it is difficult to know which is the spiral side, it may nevertheless always be ascertained by a careful examination."[1]

While the anatomy of *Planorbis* in its principal characters, is presumed to be sinistral, and indicates, with the sum of other characters (including habitat), a most intimate relationship to *Physa*, which has, as is well known, a sinistral shell, yet some of the authors who affirm the sinistral character of the soft parts or body, say also, that the species of this genus (*Planorbis*), have a dextral shell, an inclusive and broad statement which applies to all of the species, and apparently repeat this tradition, or else assume that it is so, because the great majority of gasteropodous mollusks which have shells at all, have dextral shells, the exceptions being comparatively few.

If we consider what are regarded as apical characters in forms about which there is no question, and it is permitted to reason, from analogy in this connection, it will be seen that some species of *Planorbis* have sinistral shells, and I submit as examples sustaining this position, the larger West American forms known as *P. ammon.* (fig. 1) Gould (+ *P. Traskii*, Lea.), *P. trivolvis*, (fig. 2) Say[2] (+ *P.* var. *occidentalis*, Cp. MSS.), *P. tumens*, Cpr., *P. subcrenatus.* (figs. 3–3*a*) Cpr.[3], *P. corpulentus*, (figs. 4–4*a*) Say, and *P. tumidus*, Pfr., from Nicaragua, also *P. corneus.* L., Britain, as shown in authentic specimens received from an experienced and

[1] Conchological Manual, p. 245.

[2] Pacific Coast specimens.

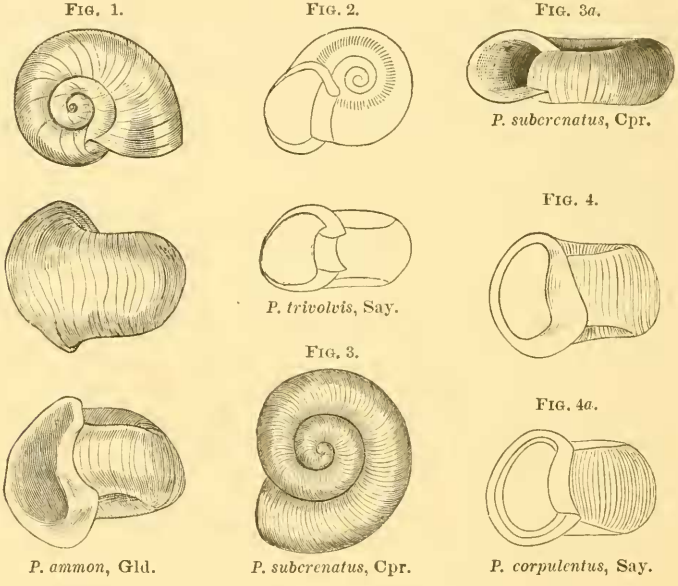
[3] This species more nearly resembles *P. corneus*, than does any other American form. Many of the smaller so-called species (American) are exceedingly close to the smaller forms of Europe, and it is not unlikely a careful investigation would place some of them under the names previously made by the earlier authors. Mr. W. G. Binney writes of *Physa hypnorum*, "it is one of the species common to the three continents;" and of *Limnæa*, he says, "It seems certain that the boreal regions are inhabited by several species common to similar latitudes in Asia and Europe, such as *L. stagnalis* and *L. palustris.*" This remark will ultimately be found to apply with equal truth to species of *Planorbis.*

trustworthy correspondent near London. This latter is the only large European species, I am familiar with.

While it is neither proven nor asserted herein, that all species of *Planorbis* have sinistral shells, neither is it known that the anatomy of all the species is sinistral.

The relations of *Planorbis* to *Limnæa* are not so remote as to make it altogether unwarrantable to look for a divergence in that direction.

The extreme variableness of *Planorbis* has undoubtedly led to the making of too many species; specimens which are conceded



to be of the same species, from different though adjacent ponds, etc., vary more or less, and this is particularly the case with West American forms which are in various degrees affected by the character of the water, temperature, etc. While it is quite certain that the specific names herein given would be reduced by a careful and philosophical comparison, at this time I can only refer to them as they now stand in the books; I may mention *P. tumens* from near Petaluma as a dwarfed variety of *P. corpulentus;* varieties of the latter are frequently confused with *P. ammon.*

It may here be remarked that Macgillivray, an enthusiastic observer, who has described some of the British species with great fidelity, lays much stress on the shape of the *mouth*, comparing it with those of *Helix* and *Zonites*, as conclusive of the dextral character of the shells in *Planorbis*.[1]

If analogies in form of mouth are worthy of consideration, though this point may not have much weight without other and corroborative evidence, we have in this character a stronger argument the other way, by, more properly a comparison between nearer related forms like *Physa* (that is the more globose species), and most of the forms of *Planorbis* I have given, holding the latter in a normal sinistral position, when the tendency to the physoid mouth, the ovate shape and sag of the aperture will be readily noticed.

Frequently, immature, half-grown, and less than half-grown shells of *Planorbis* have been brought to me by collectors who were quite confident they had made new discoveries, and it is not improbable that young shells as above have been described and published as new species of *Physa*.

FIG. 5. FIG. 6. FIG. 7.

Ameria scalaris, Jay. *Physa globosa*, Hald. *Physa humerosa*, Gld.

FIG. 8. FIG. 9.

Physa ancillaria, Say. *Physa ampullacea*, Gld.

I would further suggest a comparison of the apertures of our larger Californian (adult) shells of *Planorbis*, held in a sinistral position with *Ameria scalaris* (fig. 5)[2] (= *Paludina scalaris*, Jay), a curious Florida form; *Physella globosa* (fig. 6), Hald., a Tennessee

[1] It is presumable that the shells of *Planorbis*, by which Macgillivray was impressed and which were the most familiar to him, were the small species of his own country, which are flat, symmetrically coiled, regular in form, and gradual in growth, being in striking contrast with the sturdier, ventricose West American forms I have cited—which also more conspicuously exhibit sinistral characters.

[2] Dall says: "A careful examination of a number of specimens of this singular form, shows that it is distinct, and not a young *Planorbis*, as has

species; also with other species of *Physa*, like *P. humerosa* (fig. 7), *P. ancillaria* (fig. 8), *P. ampullacea* (fig. 9), etc., *et sic de similibus.*

We shall, however, find more satisfactory testimony on the sinistral point by analyzing the apical characters.

If, as in other shells, we consider that to be the upper end or spire in which we can follow the volutions through the entire shell from tip or nucleus to the ultimate or basal whorl and mouth—then it is impossible to avoid the conclusion that some species of *Planorbis* have sinistral shells. In some of the smaller forms, like *P. vortex*, *P. contortus*, *P. glaber*, *P. carinatus*, and *P. spirorbis*, all of which are British species, and in which the whorls are (in comparison with larger American forms) quite evenly coiled and in which also, the increase in size of whorl is quite gradual, the difference between the two sides of the shell, apical and umbilical, is not as readily perceived. The largest British species, *P. corneus*, confirms my view, being sinistral. The rapid enlargement of the whorls in some of the West American species is in marked contrast with even the shells of *P. corneus* of the same diameter; the height of the latter as compared to *P. corpulentus* being as ·31 to ·54, while the length of the aperture is in still greater contrast, being as ·42 to ·76. These measurements were made from average-sized perfect specimens of both species placed apex up, with the mouth to the left,

It is easy to perceive that in those forms where the ratio of increase is great as between the last whorl and the preceding volution and so on, whorl compared with whorl, through the whole, as for instance in *P. ammon*, that the depression of both spire and umbilicus is most marked; but nevertheless the umbilicus is the more profound as may easily be proved by counting the volutions first on one side, and then on the other.

Again, if additional proof is wanted, take any one of the larger forms[1] of the species herein named, and carefully, by degrees, burn off the under side (which can easily be done, by pouring a little

been suspected.—*Annals N. Y. Lyceum Nat. Hist.*, Vol. IX, p. 356; footnote.

[1] As distorted individuals, with the volutions exceedingly irregular, are of frequent occurrence, in making the test suggested, such monstrosities should be rejected, as they would as often *unduly* favor one side of the question as the other.

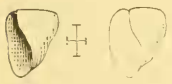
acid in a saucer or watch-glass), until the shell is eaten off to a line which obliterates the umbilicus, when the nucleus of the spire, the tip, and half a whorl to a whorl and a-half will be found remaining.

Those who insist on the dextral character of the shells in *Planorbis*, unless they except the species I have named, are thus compelled to demonstrate how in the sequence of growth the umbilicus can precede the nucleus.

Though specimens of the forms under discussion, in various embryonic stages, have frequently excited my attention, yet the material, so far as adolescence is connected with the present line of inquiry, was at the moment, unfortunately, inaccessible. I have therefore been compelled, in order to present such structural features of the shells as are related to the direction (right or left) of the volutions, the form of the aperture, etc., to use adult specimens, and by breaking back, piece by piece, and whorl after whorl, towards the nucleus, until the larger whorls are sufficiently removed, so that the apex or spire ceases to be either concave or depressed, and is simply flat. It would be almost, if not quite impossible to do this with the smaller species, owing to their diminutive size and exceeding fragility, and difficult to obtain the necessary sections for illustration herein, by the use of acid.

The figures (10) are drawn from specimens of *Planorbis corpulentus* collected in Oregon, also in Clear Lake, California, by that indefatigable collector, Mr. C. D. Voy. Before manipulation they measured as follows:

FIG. 10.



Plan. corpulentus—nuclear whorls.

Largest diameter, . . ·94 inch.
Height, ... ·38 inch.
Number of whorls, four and a-half,

which were broken back to one and a-half whorls, with a diameter of ·10 inch.; height ·15 inch. The umbilicus in one instance was still discernible—in the others, destroyed. This species is widely distributed and occupies an extensive geographical area, on the western side of the continent, from the Columbia River in the north; easterly to Lake Winnipeg; and southerly to Cape St. Lucas.[1] Binney says, "*P. corpulentus* is catalogued from Guatemala by Mr. Tristram."

[1] Prof. Geo. Davidson collected specimens at this place.

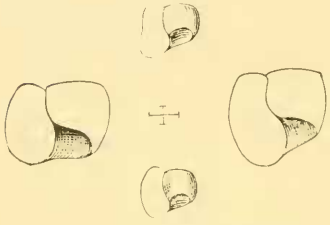
P. Traskii, Lea, which Mr. Binney makes a synonym of *P. ammon*, belongs to the western *corpulentus* form.

While the foregoing figures (10) show the shells of one species reduced to one and a-half whorls, the following figures exhibit the form of *Planorbis tumidus*, Pfr., which measured in

Largest diameter, ...68 inch,

with five whorls, reduced by breaking down to two and a-half whorls and a diameter of .16 inch.

Fig. 11.



Plan. tumidus—nuclear whorls.

This last is a more southern species; numerous specimens were collected by the late Thos. Bridges, who found them abundant in elevated pools, small lakes, etc., amid the forest slopes of Mombacho, in Nicaragua. It closely resembles more northern forms and should hardly be called a species.

It will be observed in the figures (10) that we have in the embryonic shells of *Planorbis corpulentus* a near approach to *Physa*, a close resemblance to a *Physa* with a flattened spire; suggesting such physoid forms as *P. humerosa*, while the adolescent stage of *Planorbis tumidus* (at half its adult size) also suggests an umbilicated *Physa* with a flattened spire, somewhat like (N. W. American) *Physa Lordi* (fig. 12), with the spire cut off, and an umbilicus punched in, back of the mouth.

Fig. 12.

Physa Lordi.

Fig. 13.

Physa planorbula.

The first figures (10) explain De Kay's "*Physa planorbula*" (fig. 13), and also suggestively point towards *Ameria scalaris*. These figures also exhibit the physoid mouth, and show that there is neither necessity nor propriety in leaving closely related forms for more distant analogies. In this connection it should also be kept in mind that certain species of *Physa*, included in Ehrenberg's subgenus *Isidora*, are more or less umbilicated. Of the smaller species of *Planorbis* which have passed under my examination, I have seldom found it difficult to determine the sinistral characters by a comparison of the two sides of the shell.

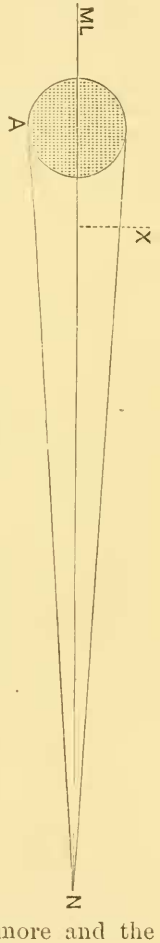
If we could unroll a specimen of, say, *Planorbis spirorbis*, and

then straighten it out, it would resemble, in minature, an acutely elongated conical tube, in a general way like the following figure:

Fig. 14.

of which N represents the nucleus, A the aperture or mouth, and ML a median line. Now it will readily be seen that such a tube, if simply wound up, or made into a flat coil, and during the process of winding, kept horizontally and laterally in plane with the central or median line which divides the tube into equal parts, would, in an exceedingly small shell, make it somewhat difficult to determine which was the apical or the umbilical (that is the upper or under) side of the shell, as the nucleus and nuclear whorls in such a case would be equally as perceptible on one side of the shell as on the other, and the concavity or depression of both sides would be the same, being equal to one-half of the diameter of the tube as seen at X.

Fig. 15.



The Californian species to which I have referred, instead of being represented by an attenuated tube like the preceding figure, which very slowly increases in circumference from nucleus to aperture, would if unwound, give us a more robust form, a more rapidly enlarging, conical tube, like this (fig. 15):

N being the nucleus, A the aperture, and ML the median line.

It will be seen that if this tube, commencing at N the nucleus, was evenly coiled upon the median line, the nucleus as in the first instance, though very much more depressed, owing to the greater diameter of the tube as seen at X, could be equally well seen on the two sides, the umbilical and apical depressions being the same.

When the line of coil is other than median, and the greater portion of the tube or shell is below the line of coil, as is the case with the species I find to be sinistral, then of course the umbilicus is the more and the

apex the less depressed, and therefore the latter is more easily discerned. Another point too important to be overlooked, is the form of the tube as exhibited in a transverse or cross section; whether circular, semilunar, or horizontally or perpendicularly ovate.

Some of the larger species have tubes, which, in cross section, are of the latter shape, hence the physoid aspect of the aperture both in adult and embryonic specimens.

Since the foregoing was written, the shells which appear in the list appended hereto as from Lake Simcoe, came to hand. The lot embraced three species of *Planorbis*. Several specimens (of rather small size) of *P. trivolvis*, are of the western *P. corpulentus* character, and *sinistral*. Twenty-five specimens of *P. campanulatus*, Say, are also sinistral as described by that author, and three specimens of *P. bicarinatus* are *dextral*, though described as sinistral by Say. Of the smaller American species glanced at by me in the course of investigation, I find *P. vermicularis*, from Utah Lake, U. T., is sometimes dextral.

From what is presented above it will, I think, be admitted that some species of Planorbes have shells whose structure is in harmony with the sinistral characters of the anatomy, as might reasonably be presumed, and it is not unlikely that such will prove to be the rule and not the exception, when an extended and critical examination of the whole group has been made.

I do not propose, at this time, to inquire into the origin of the related forms referred to in this paper; but the suggestions, which have incidentally occurred in, or grown out of the consideration of the simpler points discussed, impress me as inviting investigation.

The following species of *Planorbis* from the localities stated, have been especially examined in connection herewith.

*	*P. trivolvis*,	Erie Canal, N. Y.
*	"	Tinker's Creek, Lake Co., Willoughby, O
*	"	Foot's Pond, Woodburn, near Cincinnati Ohio.
*	"	Lake Winnebago, Wisconsin.
*	"	Wabash River, Posey Co., Indiana.
*	"	Covington, Kentucky.
†	"	Washoe Lake, Nevada.

NOTE.—I am indebted to the courtesy of the Smithsonian Institution *for all* of the figures herein, *except* 10, 11, 14 and 15, which are original.

‡	*P. trivolvis*,	Near Salt Lake, Utah T.
§	"	Utah Lake, U. T.
*	*P.* between *lentus* and *glabratus*,	Carthage, Ohio.
*	*P.* approaching *glabratus*.	Cumberland Co., Tennessee.
*	*P.* approaching *lentus*.	Cumberland Co., Tennessee.
‡	*P.* near *tumens*,	Tuolumne Meadows, Tuolumne Co., Cal.
*	*P.* near *corpulentus*,	Indian River, Texas.
*	" "	Bexar County, Texas.
*	" "	Miami, Florida.
††	" "	Lake Simcoe, Canada.
‡	*P. corpulentus*,	Near Portland, Oregon.
††	"	Lake Simcoe, Canada.
†	" var. *Traskii*,	Clear Lake, Lake Co. Cal.
	" "	Oregon, Mus. Stearns.
‡	*P.* var. *occidentalis*, Cp.	Russian River, near Ukiah, Cal.
††	" "	King's River, Cal.
††	" "	Mountain Lake, near San Francisco, Cal.
†	" "	Santa Cruz, Cal.
‡	*P. tumens*,	Los Angeles, Cal.
‡‡	*P. tumidus*,	Nicaragua.
*	*P. glabratus*,	East Tennessee.
*	*P. bicarinata*,	Erie Canal, N. Y.
*	"	McHenry County, Ills.
‡	"	Portland, Oregon.
††	"	Lake Simcoe, Canada.
*	*P. lentus*.	Clear Lakes of Indian River, Florida.
*	*P. campanulatus*,	Orono, Maine.
*	"	Henry County, Ills.
‖	*P. ammon*,	Salinas River, Cal.
¶	*P. corneus*,	Great Britain, many localities.

The note marks above refer to the following parties from whom the material examined was received: * Prof. A. G. Wetherby; † C. D. Voy; ‡ Henry Hemphill; †† A. W. Crawford; § Dr. Edward Palmer; ‡‡ the late Thomas Bridges; ‖ O. Button; ¶ the late W. W. Walpole, Esq., from all of whom I have received most generous assistance.

As to the validity of the species, or determinations as above, it is not necessary to discuss the matter in this paper, as it is not pertinent to the objective point, but as may naturally be supposed by any one who has had occasion to examine into the literature relating to the group, and to make a critical comparison of mate-

rial, I have found much that is unsatisfactory, and it is not asserting too much to say, that too many species have been made, and that a careful revision is required; and in this connection, which shows the well-known variability of the group, I may mention the examination of a parcel of specimens from a single "pond back of Covington, Kentucky," kindly furnished by Professor Wetherby, which admits of a separation resulting in three species and a remainder which readily connects all three; for this reason I do not claim that the determinations as given are always consistent, though carefully considered; as before remarked, however, the point I have endeavored to present is not affected thereby.

II. *On certain Aspects of Variation in American Planorbes.*

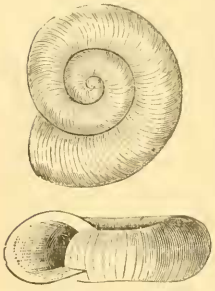
In the course of the preceding inquiry various aspects of variation, as exhibited in the material under examination were constantly recurring.

Without presuming to explain such phenomena, which would quite likely be a difficult matter, even if all the peculiarities of environment in each case, or of each lot of shells examined, were known, and without such data, quite hypothetical, yet a few notes and comments suggested by the forms referred to, may be worth a passing notice.

The larger so-called species of *Planorbis* may for convenience in discussion be grouped as follows:

First. Those in which the whorls are rounded; that is to say if the tube or cone, as represented in the preceding paper, was cut transversely, the section would show a rounded (not round) outline. Examples—The typical *P. corneus*, L.,[1] of Europe; *P. Guadaloupensis*, Sby.;[2] *P. subcrenatus* (figs. 16, 17), Cpr.,[3] and *P. tumidus*, Pfr.,[4] of Nicaragua, a quite persistent form, not, however, quite as rounded as the others.

Figs. 16 and 17.



P. subcrenatus, Cpr.

Second. Those in which the whorls are either planulate, angulated, carinated or subcarinated, which includes most of the larger

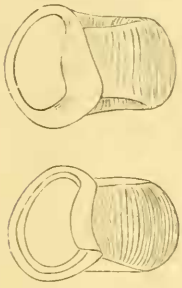
[1] Woodward's Manual, Pl. XII, fig. 34; Sby.'s Manual, Pl. XIV, fig. 311; Reeve, Conch. System., Pl. CXC, fig. 1.

[2] Ibid, fig. 2.

[3] Binney, L. and F. W. Shells, N. A., Part II, figs. 176, 178.

North American species. Examples—*P. corpulentus* (figs. 18, 19), Say,[1] *P. Traskii*, Lea., *P. occidentalis*, Cp., and *P. bicarinatus* (fig. 20), Say. In these the tube, if cut transversely, would present an outline more or less angulated.

Figs. 18 and 19.



P. corpulentus, Say.

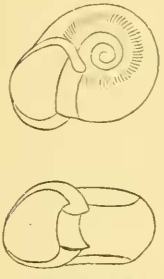
Fig. 20.

P. bicarinatus, Say.

Forms like *P. trivolvis* (fig. 21), Say, connect the two groups; for while in some instances this species exhibits the rounded whorls of the first, it imperceptibly differentiates from the above to obtuse angulation, and thence to the subcarinate forms of the second group.

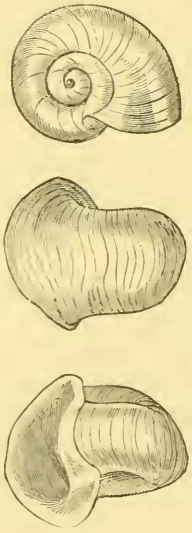
P. ammon (fig 22), Gould, must be mentioned here, as it illustrates another aspect of variation, that of a more rapid enlargement of the whorls, the result of a more obtuse cone than in *trivolvis;* this, when flattened above or angulated, gives us the form *P. Traskii*, the most striking of all the American Planorbes; it is the extreme or culmination of the flattened or planulated aspect in the second group of species, of which *P. corpulentus* is a well known form and more widely distributed than the other; Dr. Cooper's *P. occidentalis* being an intermediate link between typical *P. trivolvis* and ordinary average specimens of *P. corpulentus*.

Fig. 21.



P. trivolvis, Say.

Fig. 22.



P. ammon, Gld.

Southern specimens of *P. trivolvis* seem to be nearer the southern form of *P. lentus* than do average specimens of these alleged species from northern stations; and both of the above from southerly stations approach more closely to the European *corneus* than do northern specimens of the same; the same may be said of the Nicaraguan *P. tumidus*.

[1] Binney's figures, ibid.

P. bicarinatus, the cone of which is less robust than that of *P. ammon* or *P. Traskii*, being in that respect nearer to the typical *trivolvis*, exhibits the culmination of the carinated or keeled character of the second group, and appears to mark the limit in this direction, having reached what may be termed a permanent point. This species is usually quite persistent as to plane of coil; though in Binney it is reported from a single station as far south as "Northern Georgia"—it seems to prefer northerly regions.

It is apparently of rare occurrence west of the Rocky Mountains. Mr. Hemphill informed me that he detected two or three individuals at Antioch, California, a station peculiar in its enviromental characters, being at a point where the Sacramento and San Joaquin Rivers meet and unite the drainage waters of the two great valleys of the same names; mingling in combined volume their fresh water with the salt tidal-water from San Francisco Bay. Other forms are sometimes found at this point; they seem unable to obtain a foothold or to establish a permanent colony or settlement. The region is one of marshes, which sustain a rank growth of coarse vegetation, especially what is known as *tules*, which sift, as it were, the waters, and hold for a time forms which, during the great floods of excessively wet winters, are swept from their native haunts through the submersion or overflow of the ponds, lakes and streams of a vast interior region.

Thus Mr. Carlton[1] found a few juvenile specimens of *Carinifex* here in May, 1869, which, like Mr. Hemphill's specimens of *P. bicarinatus*, had never before nor, so far as I can learn, have never since been reported from this place nor any point in the adjoining region. In fact, the only habitat west of the Rocky Mountains, I believe, from which this *Planorbis* is reported on good authority, is Oregon; I have specimens from Portland, collected by Mr. Hemphill.

A frequent aspect of variation in the forms falling within the first group, is that of occasional bulgings or swellings, as seen in *P. glabratus*, Say, and *P. tumens*, Cpr., suggesting periodicity in growth, or rather periods of hibernation or rest, and periods of activity, at the termination of which a mouth or expansion of the

[1] Proc. Cal. Acad., Vol. IV, p. 50.

aperture, analagous to a varix, is formed—and this repeated as the animal advances towards maturity, imparts to the shell its special feature. It will be readily seen by this, that any of these forms, scattered or distributed over a wide region in northerly or extremely elevated stations, where the season of cold reaches a maximum, against which protection must be sought by hibernation, might in some of their colonies be subjected to such conditions, and hibernation be the only protection, as in the land snails of arid regions, against seasons of excessive drought, and in other regions against the cold of winter; and bulged or varicose variation be produced in a perfectly simple way, that is, in harmony with or through the operation of a general law; and this variation be perpetuated for some time in colonies migrating from such stations to a more genial habitat; until after awhile, some of the descendants of these varicose ancestors reach places where hibernation is unnecessary by reason of a permanency or mean of conditions—temperature, supply and quality of water being in equilibrium with the usual requirements of these animals—and the ordinary smooth, evenly-grown shells again prevail through reversion to the original form.

To return to the groups, as above, the Covington Pond specimens referred to in part first, connect said groups, being what may be called "*trivolvis*, with variations"—that species or general form being, through its plasticity, the connecting link.

Still another aspect of variation is shown in Ingersoll's[1] *P. plexata*, from St. Mary's Lake, Antelope Park, Colorado. Here we have a variation not unusual in the various Planorbes, and not confined to any of the larger species, that of irregularity in winding, as if through extreme torsion the coil cockled; the whorls twisting off the line or plane of volution. *P. plexata* is an eccentrically coiled *trivolvis*, the deviation from plane of volution having somewhat of regularity of occurrence, and not improbably owing to the same cause as that to which I attribute the bulging in the *glabratus* form, namely—to recurring seasons of hibernation and activity, when the new growth hardly makes a "good joint" as a mechanic might say, with the edges of the previous mouth; the heavy water plants at the bottom of the lake described by Mr. Ingersoll, quite likely perform a part, in causing or contributing to the irregular winding of the shell at

[1] See Hayden's Reports Territorial Surveys, 1874, p. 402.

the time when a new growth commences—when the shell *which is to be* is hardly more than plastic membrane, not backed up with a stiffening of lime, as it is after the fabric is perfected.

In Mountain Lake, near San Francisco, a few miles west of said city, curiously distorted pond snails of the genus *Physa* occur, which at one time, some years ago, excited attention. The season of their growth is the summer, and its generative warmth is accompanied with the trade winds, which blow across the lake with considerable violence; the plastic shells of the Physæ are forced against plants, chips and various fragments, odds and ends afloat in or around the lake; and the outer lip thus gets dented and bent, giving a curious twist to many of the individuals. A figure (128) illustrating a distorted specimen from the foregoing locality is given by Mr. Binney in his L. and F. W. Shells of North America. However, I have no reason to believe that this deformity is transmitted, as only a small proportion of the multitude are affected.

The specimens on which Mr. Ingersoll's species is based, were found by him, as stated, in a snow-fed pond of small size, between or among high cliffs. As before implied, the vacillations in plane of coil may be owing to interruption of growth by recurring periods of hibernation, the characters in the environment, mentioned by Mr. Ingersoll, affording a reasonable solution of the phenomena. Such ponds are subject to marked climatic contingencies; and sometimes, or rather in some years, their basins are nearly or quite dry—and again, fluctuations of temperature, according to the volume of water, which is an important factor, are far more critical in small ponds than in lakes or large bodies of water, where the extremes of temperature, as well as other conditions, as quality of water, are less variable or extreme.

These two aspects of variation, bulging and irregularity in coiling are exhibited with more or less frequency in all of the larger American species, and in a greater or less degree, throughout the entire area inhabited by *Planorbis;* occurring oftener, perhaps, among colonies which inhabit elevated stations, than with those living at altitudes nearer the level of the sea. I am of the belief, too, that these aspects of variation are less frequent among colonies inhabiting southerly and semi-tropical regions.

All of the variations referred to are, when present, more conspicuous in the larger forms west of the Rocky Mountains, for

the reason that some of them reach a size very much in excess of the largest individuals of the same species, from points east of said range.

The carinated and planulate forms seem to be freer from the bulging or variceal peculiarity than the others.

As to the relations of the various species to each other, or their interrelations, it is quite evident that many of them have an immediate common ancestry. *P. trivolvis* (+ *P. trivolvis* var. *fallax* + *P. lentus*) of the American species appears to be the dominant stock-form, and may be regarded as Americanized *corneus*, if a semi-political term may be used in a physico-geographical sense; its presence in the company of such forms as *Limnæa stagnalis*, *L. palustris* and others, of circumpolar distribution, indicates a geographical identity with the European species.

While the Planorbes attain their maximum of size in that part of North America west of the Rocky Mountains and north of latitude 30° N., the number of supposed species, or of forms which present characters more or less distinct, are more numerous east of said range.

There is apparently no relation between altitude of habitat and size of shell. The quantity of West-coast material accessible at this moment is too small to enable me to give a satisfactory exhibit of measurements. The following will, however, convey a fair idea of the robust proportions of the more conspicuous West-American forms, the first and second being *P. trivolvis* and the third *P. ammon*.

1. Utah Lake, U. T., elevation 4498·5 feet. Greater diameter 1·41; lesser, 1·04 inches. Long. of aperture ·71; longitudinal diameter of whorl at juncture of parietal callus ·45 inch.

2. Washoe Lake, Nevada, elevation 5006 feet. Greater diameter 1·30; lesser, 1·01 inches. Long. of aperture ·60; long. of whorl at junction of parietal callus ·47 inch.

3. Salinas Valley, Cal., elevation 100— feet. Greater diameter 1·24; lesser, ·98 inch. Long. of aperture ·90; long. diameter of whorl at junction of parietal callus ·55 inch.

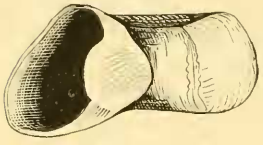
4. Clear Lake, Cal., elevation 1323 feet. Greater diameter 1·05; lesser, ·74 inch. Long. of aperture ·77; long. diameter at junction of parietal callus ·76 inch.

This last (4) is a typical *Traskii*. A comparison of the meas-

urements of the aperture and of the whorl at the junction of the parietal callus in this and 3 (*P. ammon*), with similar measurements in 1 and 2 (*P. trivolvis*), will give a good idea of the relative obtuseness of their cones or tubes, as well as of the inflation or patulous aspect of the aperture, and of its effect on the physiognomy of the shell. A typical *P. corneus* (British specimens) of 1·10 inches greater diameter measures ·87 inch lesser diameter, while the longitude of aperture is ·42, and longitudinal diameter at junction of parietal callus is ·30 inch.

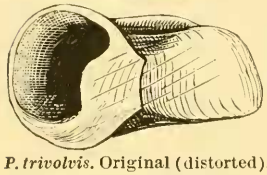
The following original figures from nature, show the Washoe Lake form as above (fig. 23); while fig. 24, from the same locality, also illustrates the distortion resulting by deviation from or eccentricity in plane of coil.

Fig. 23.



P. trivolvis. Original.

Fig 24.



P. trivolvis. Original (distorted).

The sinistral or dextral inquiry led to the discovery that *P. bicarinatus* is sometimes right and sometimes left; this is an interesting fact, because said species exhibits certain analogies with other peculiar and characteristic forms.

The relations of the dextral *Carinifex*, whose planorboid character led Dr. Lea[1] to describe it as a *Planorbis*, are apparently closer to *P. bicarinatus* than to any other species. The exceeding variability of *Carinifex* is seen by the figures here given, which, however, do not fully represent the range of variation. (Figs. 25, 26, 27).

Fig. 25.

From Lea's types. Klamath and Canoe Creek specimens.

Fig. 26.

Fig. 27.

Variety from Pitt River, Cal.

From Lea's types. Klamath and Canoe Creek specimens.

Carinifex Newberryi, and varieties.

In the light of our present knowledge it should perhaps be regarded only as a coincidence that the very territory from which *P. bicarinatus* is with the two exceptions of Hemphill's Antioch, and Portland (Oregon) localities, entirely absent, is the territory inhabited by *Carinifex*, and in which it has been found, either recent or fossil. When the immense area of this territory is considered, the number of localities in which it has been detected, are few; still these few are so related the one to the

[1] Binney's L. and F. W. Shells of N. A., Part II, p. 74.

other as to indicate a wide and general distribution within its boundaries. These localities are as follows, commencing at the easternmost station:

1. Utah Territory; near Utah Lake, in Wahsatch Mountains, collected by Dr. Edward Palmer. Museum Stearns. (Semi-fossil.)

2. Nevada (Tertiaries); as *Vorticifex Tryoni*, Meek, in King's Survey.

3. California; Owen's Valley, collected living by Hemphill; "The most southern locality. The animal undistinguishable externally from that of *Planorbis ammon*." Cooper.

4. California; Klamath Lake and Canoe Creek, living; Dr. J. S. Newberry. S. I. Collection.

5. California; Pitt River, Dr. Cooper; living. S. I. Collection.

6. California; Clear Lake, living; Dr. Veatch. S. I. Collection. Cooper makes a var.? "minor" of specimens from this place.

7. California; Antioch; living. Carlton. "A few very young ones, perhaps a dwarfed southern variety like those from Clear Lake."

8. California; Livermore Valley, Alameda County; "in the hills north of Martin's, near Tassajara," Cooper, fossil; label marked "Planorbis, etc., Tertiary?" in State Geol. Survey Coll., Univ. of Cal.

The Utah specimens, though small, are mature, and include the form rounded above like Meek's Nevada species, as well as the more flattened and grooved features of the Tassajara[1] specimens, which approach in size and general characters more closely to Lea's type, fig. 25. Some of Palmer's Utah specimens are elevated, and vary in the direction of fig. 27, though not terraced or keeled as much; the lot of only a dozen specimens, exhibits a remarkable range of variation.

There are striking analogies between the shells of *Carinifex* in its varieties, and the Australasian brackish water *Amphibolæ*.

A new species has been made on one of the varieties by Mr. Smith, of the British Museum, which he named *C. Ponsonbii*;[2]

[1] Tassajara is the name of a stream which is frequently dry in the latter part of summer.

[2] Proc. Zoöl. Soc., 1875, p. 536. Also Quar. Jour. Conch., Vol. I, p. 150.

the specimens were collected by Lord Walsingham, in *California*. There are several varieties still undescribed, which challenge the attention of those who are ambitious in this direction.

Carinifex exhibits many of the variations in form of tube or cone, in cross-section, which are seen in *Planorbis*, without the bulgings of the varicose forms, and *plus* the elevation of spire which is seen especially in extreme individuals like the figure; the outline of the mouth is very much like that of *P. bicarinatus*, and in some of its varieties suggests a *P. bicarinatus*, with the umbilicus deepened by pushing up the spire from below. With the discovery of new localities, and ample material both recent and fossil, without doubt the sequence of variation will be traced, and its relation to meteorological, geological and chemical changes, within the area of its distribution partially indicated.

In this connection I would direct attention to Prof. Hyatt's interesting letter to Mr. Ingersoll, referring to Steinheim fossils, and to the *Valvatæ* of Lawlor's Lake, Nova Scotia, in Prof. F. V. Hayden's Report, 1874.